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L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

Climatology as a Function of Map Type

IVER A. LUND

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Abstract

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Climatology as a Function of Map Type

1. INTRODUCTION

A map-pattern classification method that is suitable for use on high-speed computers was developed by Lund (1963). After a few rather arbitrary decisions, the method is completely objective. The decisions involve such matters as the size of the geographical area, location of the observation points, threshold value of the correlation coefficient, and data sample. The method is sufficiently general to permit classifying multiple events whether or not they can be depicted on a map. The only requirement is that the events be expressed numerically.

In common with other methods, many variations of the procedure are possible. The purpose of this paper is to explore some of these variations. Other variations have already been examined by Godske (1965), Bjorem (1966), Augulis (1969), Hartranft, Restivo and Sabin (1970a, 1970b) and others.

In this study four variations of the 1963 procedure were used to develop sets of map types for the purpose of determining the "best" variation. The first variation closely paralleled the procedure described in the 1963 article; the maps were classified without regard to the current, or subsequent weather, and a single map was used as a type. The second variation resembled the first except the map types were averages of a number of similar maps. The third and fourth variations were the

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same as the first and second, respectively, except the data were stratified according to the subsequent weather before the map types were developed. The variations will be illustrated with an example in the following sections.

2. PROBLEM

The problem was to develop a forecast aid to estimate the probability of four categories of future six-hourly precipitation amount at Travis Air Force Base, California, in winter. It was assumed that either an 0400 LST synoptic chart, or an accurate prognostic chart valid at 0400 LST, of the 1000-mb surface would be available for use in preparing the probability estimates of subsequent precipitation categories.

3. PREDICTAND

The daily total amount of precipitation observed during the six-hour period between 0400 LST and 1000 LST was divided into the four categories shown in Table 1. (The following abbreviations will be used throughout this paper: LT = less than; LE = less than or equal to; GT = greater than; and GE = greater than or equal to.) The data sample consisted of 585 days from the months of December, January and February between December 1963 and February 1970. Data for 47 of the 632 possible days were not used because 1000-mb data were not available.

Table 1. The Four Precipitation Categories and the 1000 LST Relative Frequency of Occurrence (Estimate of the Probability) of Each

| Category | Precipitation (P) | Frequency (Cases) |
|----------|-------------------|-------------------|
| A | P = 0.00 | 67.9% (397) |
| B | P = Trace | 13.2% (77) |
| C | P GE 0.01 LE 0.10 | 11.1% (65) |
| D | P GT 0.10 | 7.9% (46) |

4. CONDITIONAL CLIMATOLOGY

Table 2 shows the relative frequency of occurrence (estimate of the probability) of each six-hourly precipitation category reported at 1000 LST as a function of the category reported at 0400 LST, six hours earlier. All categories tend to recur much more frequently than expected from the unconditional climatology.

Table 2. The Conditional Relative Frequency of Occurrence (Estimate of the Probability) of Each Six-Hourly Precipitation Category Reported at 1000 LST as a Function of the Category Reported at 0400 LST, Six Hours Earlier. The unconditional relative frequencies (from Table 1) are shown in parenthesis

| | | Category at Subsequent Hour (1000 LST) | | | | Sample Size |
|-------------------------------------|-----|--|--------|--------|-------|-------------|
| Category at Initial Hour (0400 LST) | | A | B | C | D | (N) |
| | A | 85(68) | 9 | 4 | 2 | 421 |
| | B | 34 | 43(13) | 17 | 6 | 53 |
| | C | 26 | 19 | 30(11) | 26 | 70 |
| | D | 7 | 7 | 41 | 44(8) | 41 |
| Sample Size | (N) | 397 | 77 | 65 | 46 | 585 |

5. PREDICTOR DATA

The 0400 LST geopotential height of the 1000-mb surface was available for each of the 13 grid-points shown in Figure 1 for the 585 days. These data were used in developing the map types.

6. MAP-PATTERN CLASSIFICATION

The four variations of the map-pattern classification procedure discussed in the introduction were used to develop sets of map types to determine the "best" and for estimating subsequent precipitation categories at Travis AFB. These variations are described in the following four sub-sections.

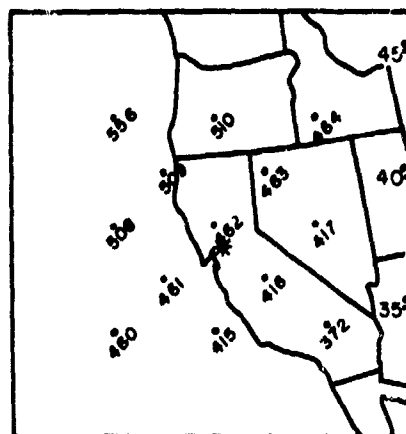


Figure 1. Location of Grid Points. The asterisk marks the location of Travis AFB, California

6.1 General Types

The 1000-mb geopotential height maps were classified without regard to the current, or subsequent weather, and a single most representative map was used for a particular type. Map types were selected by the following procedure:

Step 1. The 1000-mb heights at the 13 grid-points shown in Figure 1 on each map were correlated with the corresponding heights on the other 584 maps in the data sample. This yielded 584 correlation coefficients for each map.

Step 2. The map having the largest number of correlation coefficients GE 0.90 was designated as Type I.

Step 3. Those maps having a correlation coefficient of GE 0.90 with the Type I map selected in Step 2 were removed from the sample. Type II was then selected from the remaining maps as in Steps 1 and 2.

Step 4. The above process was repeated until only a few cases with correlation coefficients GE 0.90 with any one map remained in the sample.

There were 85 maps whose correlation coefficient with the map of 8 February 1969 was GE 0.90. Since this was more than any other map, 8 February 1969 was selected as Type I. After the 85 maps designated Type I were removed from consideration, there remained 53 maps in the sample whose correlation coefficient with the map of 4 December 1969 was GE 0.90. The map for this date was selected as Type II. The process of removing the appropriate maps and counting the correlation coefficients GE 0.90 was continued until eight types were selected. The map types are shown in Figure 2, and Table 3 gives the 1000-mb geopotential heights associated with each type, the date of the map chosen as a type, and the number of maps highly correlated with that type.

Table 3. The 1000-mb Geopotential Heights (Meters)
Associated With Each of the General Map Types

| Grid Point | General Map Type | | | | | | | |
|---------------------|------------------|----------|-----------|-----------|-----------|-----------|-----------|----------|
| | I | II | III | IV | V | VI | VII | VIII |
| 372 | 169 | 116 | 123 | 224 | 158 | 112 | 133 | 139 |
| 415 | 169 | 138 | 139 | 226 | 163 | 149 | 173 | 154 |
| 413 | 176 | 134 | 163 | 242 | 146 | 123 | 144 | 160 |
| 417 | 183 | 137 | 222 | 286 | 125 | 82 | 113 | 190 |
| 460 | 131 | 189 | 182 | 210 | 155 | 194 | 183 | 210 |
| 461 | 139 | 170 | 173 | 232 | 140 | 171 | 169 | 197 |
| 462 | 151 | 164 | 190 | 253 | 119 | 151 | 147 | 199 |
| 463 | 153 | 167 | 238 | 284 | 100 | 125 | 112 | 230 |
| 464 | 168 | 167 | 281 | 312 | 95 | 71 | 91 | 261 |
| 508 | 72 | 197 | 197 | 202 | 121 | 202 | 159 | 251 |
| 509 | 67 | 197 | 199 | 230 | 85 | 174 | 135 | 248 |
| 510 | 78 | 198 | 229 | 253 | 62 | 148 | 108 | 258 |
| 556 | 46 | 216 | 208 | 183 | 59 | 181 | 118 | 267 |
| Date | 8 Feb'69 | 4 Dec'69 | 20 Feb'70 | 10 Jan'67 | 29 Dec'64 | 22 Feb'65 | 15 Jan'69 | 2 Feb'64 |
| Cases GE 0.90 | 85 | 53 | 53 | 42 | 39 | 31 | 30 | 22 |

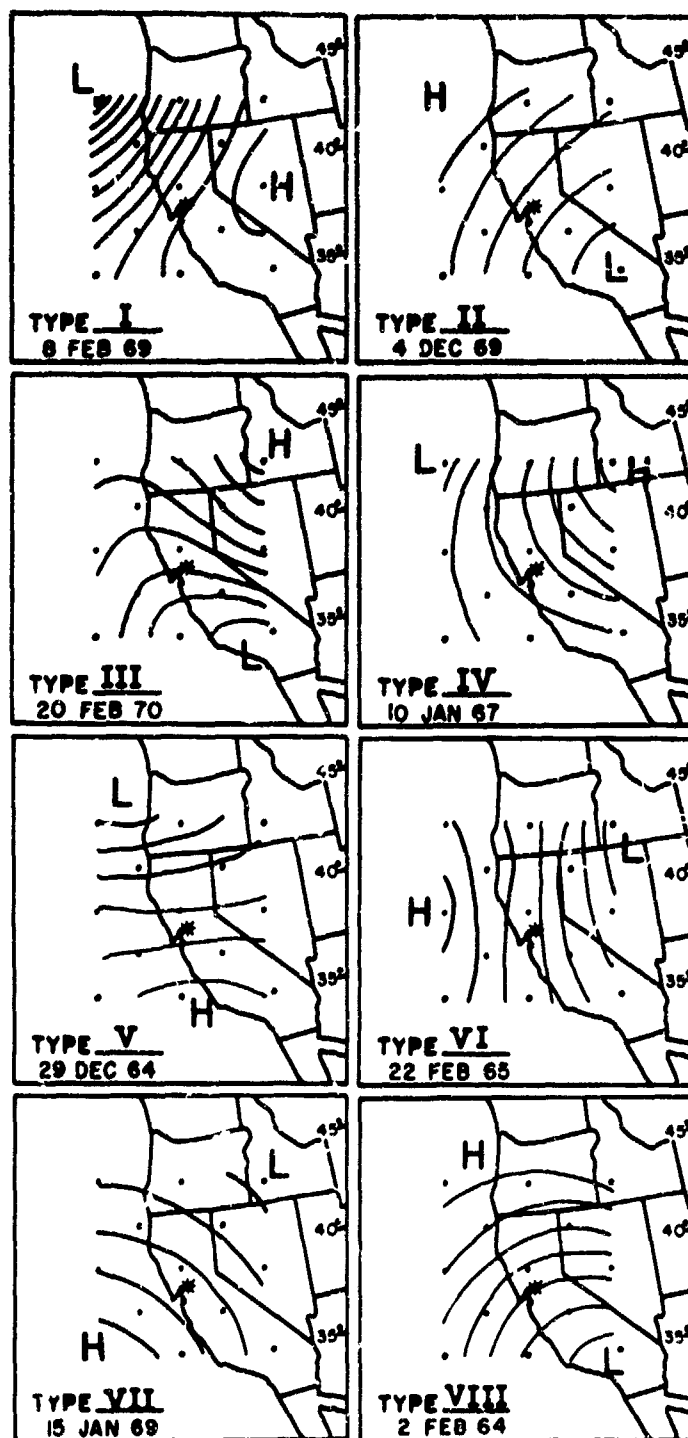


Figure 2. General Map Types Selected by the 1963 Procedure, Shown in the Order of Selection

6.2 Smooth General Types

The second set of map types were developed by selecting the first map in the same manner as described above. However, after the first map was selected, all maps with a correlation coefficient ≥ 0.90 with the map selected were averaged to obtain what was termed a smooth general type. There were 85 maps highly correlated (≥ 0.90) with the map of 8 February 1969, Type I. The 1000-mb heights at each grid-point on each of these 85 maps were averaged, resulting in (smooth general) Type 1. (It will be noted that Roman numerals are used to identify the "general" map types and Arabic numerals to identify the "smooth general" types.) The map of average grid-point heights comprising Type 1 was correlated with the 585 other maps, and all maps with coefficients ≥ 0.90 were classified as Type 1 and removed from the data sample. The next map with the highest number of correlation coefficients ≥ 0.90 with the remaining maps was the map of 4 December 1969. It will be noted that this map is the same map selected as Type II, but it could have been different since the procedure resulting in Type 1 did not eliminate exactly the same maps as that used to select Type I. All maps highly correlated with the 4 December 1969 map were averaged to obtain Type 2. The Type 2 cases were removed from the sample and the process continued until eight "smooth general" types were developed. Figure 3 depicts the smooth general map types.

6.3 Stratified Types

The map typing procedure followed in developing stratified map types was the same as described in subsection 6.1 except that, before the procedure was begun, the maps were divided into four parts based upon the subsequent precipitation. Part A consisted of all the 0400 LST maps preceding precipitation category A, no precipitation. Likewise, Parts B, C and D were maps preceding precipitation categories B, C and D. In an effort to keep the number of types constant for each variation and to overcome small sample sizes in some cases, only two types were identified with each of the four precipitation categories. Figure 4 depicts the stratified map types.

6.4 Smooth Stratified Types

The procedure followed in developing smooth stratified map types was the same as described in subsection 6.2 except the maps were divided into four parts, as described in subsection 6.3, before the maps were typed. Again, only two smooth stratified types were identified with each of the four precipitation categories. They are shown in Figure 5.

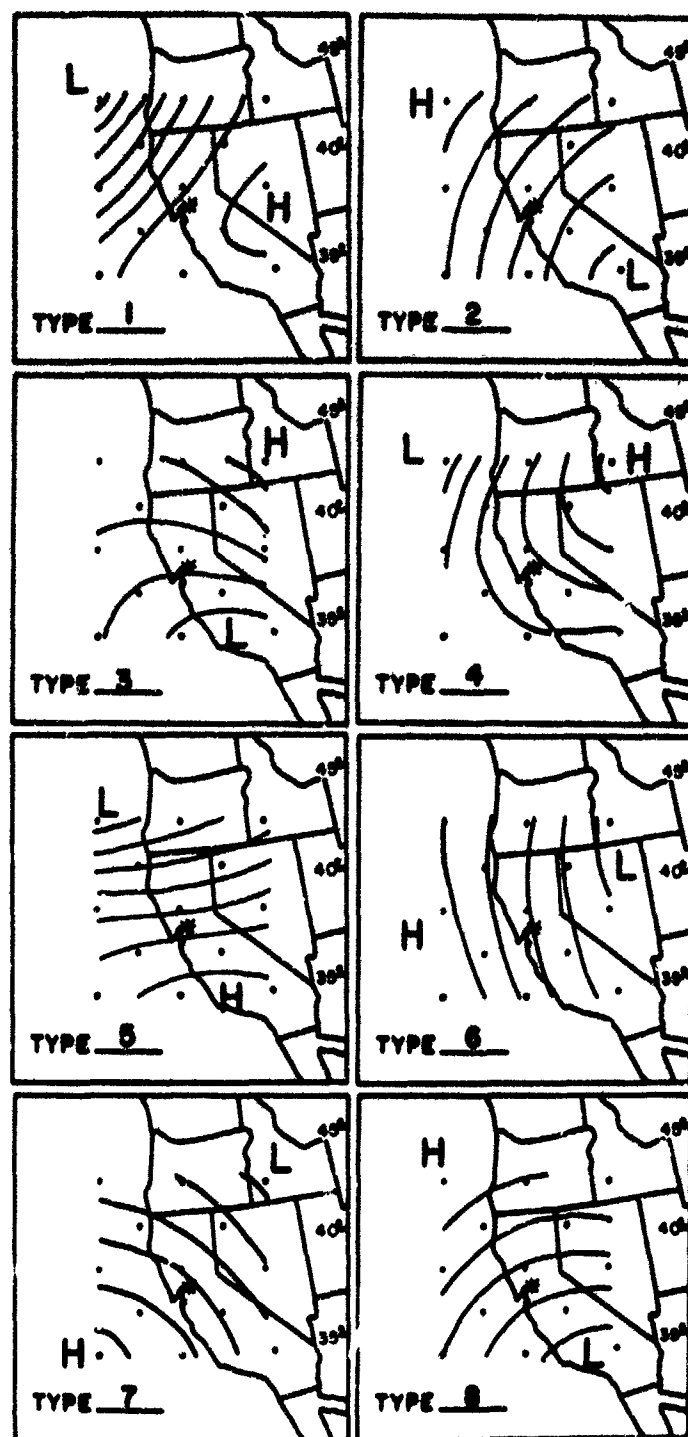


Figure 3. Smooth General Map Types Resulting From Averaging All Highly Correlated (Coefficient GE 0.90) Maps, Shown in the Order of Selection

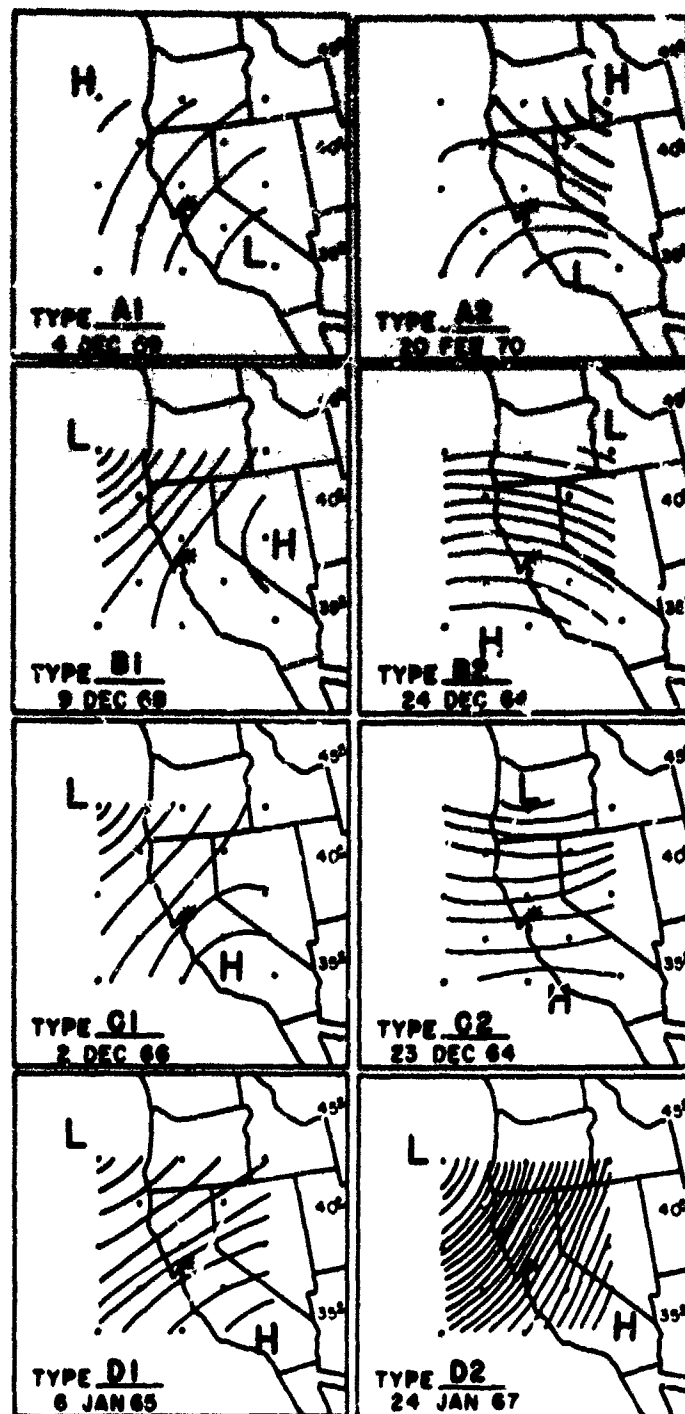


Figure 4. Stratified Map Types Selected by the 1963 Procedure After the Maps Were Stratified According to the Subsequent Precipitation Category, Shown in the Order of Selection

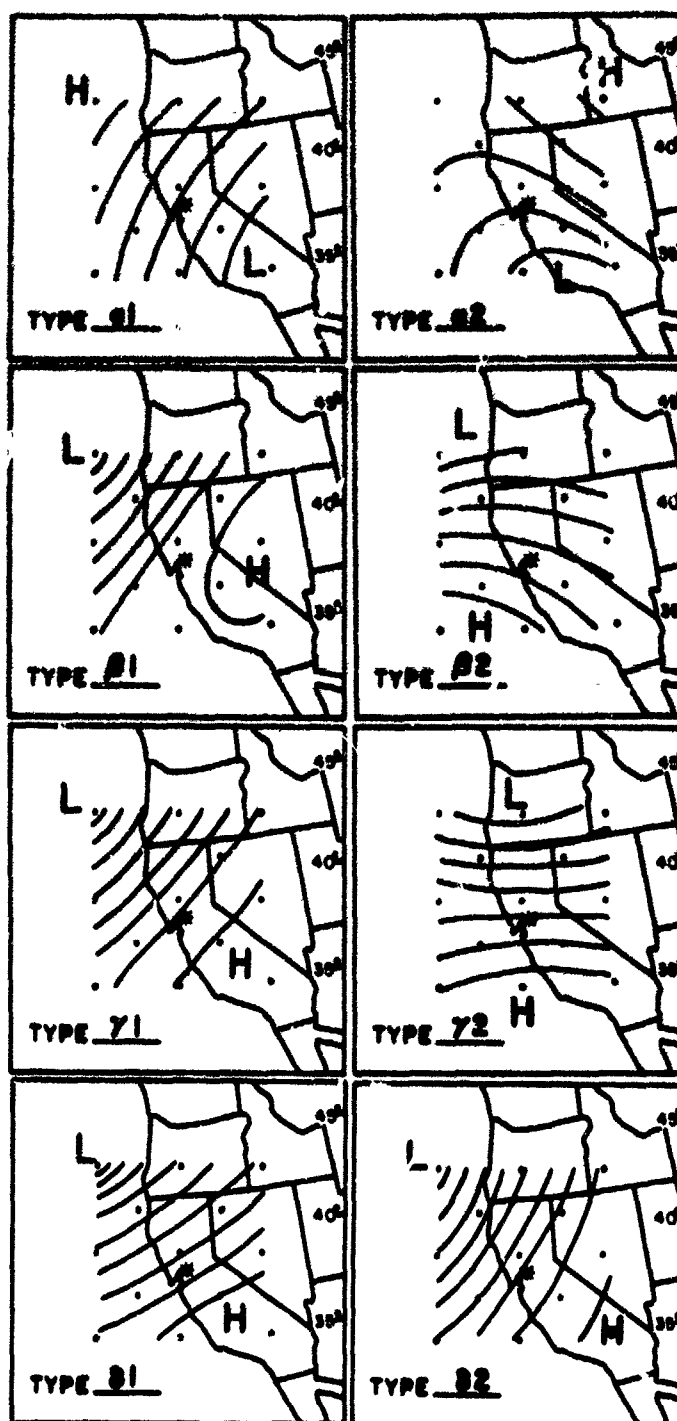


Figure 5. Smooth Stratified Map Types Resulting From Averaging All Highly Correlated (Coefficient GE 0.90) Maps Preceding the Same Precipitation Category, Shown in the Order of Selection

7. FORECASTING PROCEDURES

To evaluate the variations in map-pattern classification, forecasts of the probabilities of 0400-1000 LST precipitation amounts at Travis AFB were made using the following ten different procedures:

- (1) Forecasts of precipitation category probabilities were made based on straight climatology. That is, the estimated probabilities of categories A, B, C and D given in Table 1 were forecast for every day in the study.
- (2) Forecasts were made based on conditional climatology. That is, depending on the precipitation category at 0400 LST on a particular day, the appropriate estimated probabilities of categories A, B, C and D given in Table 2 were used.
- (3) Each of the 585 sets of grid-point geopotential heights (maps) were correlated with the corresponding heights, given in Table 3, associated with each of the general map types. Each map (with the exception of 58 maps not correlated by a value GE 0.70 with any of the types) was assigned to the type with which it was most highly correlated. The relative frequencies of subsequent precipitation categories A, B, C and D associated with map types I through VIII were determined from the 585 day sample. They are shown in Table 4. Probability forecasts were prepared for each day with the probabilities governed by the 0400 LST general map type. For example, when Type I was observed at 0400 LST the following percent probabilities of subsequent precipitation categories A, B, C and D were predicted: 40, 16, 24 and 20 respectively.

Table 4. The Relative Frequency of Occurrence (Estimate of the Probability) of Each 1000 LST Precipitation Category as a Function of the 0400 LST General Map Type

| General Map Type at 0400 LST | Precipitation Category at 1000 LST | | | | Sample Size |
|------------------------------|------------------------------------|----------|------------|------------|-------------|
| | A(0.00) | B(Trace) | C(LE 0.10) | D(GT 0.10) | |
| I | 40 | 16 | 24 | 20 | 112 |
| II | 96 | 3 | 1 | 0 | 70 |
| III | 84 | 13 | 4 | 0 | 79 |
| IV | 72 | 22 | 6 | 0 | 67 |
| V | 24 | 17 | 29 | 29 | 58 |
| VI | 82 | 14 | 4 | 0 | 51 |
| VII | 71 | 20 | 8 | 2 | 51 |
| VIII | 92 | 5 | 0 | 3 | 39 |
| K* | 74 | 5 | 12 | 9 | 58 |

*Map type K consists of all maps with a correlation coefficient LT 0.70 with all of the other types.

(4) Forecasts were made based on a precipitation climatology related to smooth general Types (1-8) as in (3) above.

(5) Forecasts were made based on a precipitation climatology related to stratified Types (A1 - D2) as in (3) above.

(6) Forecasts were made based on a precipitation climatology related to smooth stratified Types ($\alpha 1 - \delta 2$) as in (3) above.

(7) Forecasts were made based on a precipitation climatology related to both the precipitation category reported and the general Type (I - VIII) in existence at 0400 LST. That is, the relative frequencies (estimated probabilities) of subsequent precipitation categories A, B, C and D associated with 0400 LST precipitation categories A, B, C and D and Map Types I through VIII were determined and used as the forecast. Table 5 shows the relative frequencies determined from the 585 day sample. Line 1 shows, for example, that following the 61 days when the six-hourly precipitation reported at 0400 LST was 0.00 and the 0400 LST map type was I, subsequent precipitation categories A, B, C and D occurred 61, 18, 18 and 3 percent of the time, respectively.

(8) Forecasts were made based on a precipitation climatology related to both the existing precipitation category and smooth general type as in (7) above.

(9) Forecasts were made based on a precipitation climatology related to both the existing precipitation category and stratified type as in (7) above.

(10) Forecasts were made based on a precipitation climatology related to both the existing precipitation category and smooth stratified type as in (7) above.

Tables 4 and 5 show relative frequencies as functions of general map types. Similar tables were prepared for the stratified types and the smooth types but they are not shown.

8. VERIFICATION

Brier's (1950) "P" score was used to verify the forecasts of probability estimates of six-hourly precipitation categories for the ten different forecast procedures. The "P" score is expressed:

$$P = \frac{1}{N} \sum_{j=1}^r \sum_{i=1}^N (f_{ij} - E_{ij})^2$$

where in this case:

Table 5. The Relative Frequency of Occurrence (Estimate of the Probability) of Each 1000 LST Precipitation Category as a Function of the Precipitation Reported at 0400 LST and the 0400 LST General Map Type

| Precipitation at 0400 LST | General Map Type at 0400 LST | Precipitation Category at 1000 LST | | | | Sample Size |
|---------------------------|------------------------------|------------------------------------|----------|------------|------------|-------------|
| | | A(0.00) | B(Trace) | C(LE 0.10) | D(GT 0.10) | |
| 0.00 | I | 61 | 18 | 18 | 3 | 61 |
| " | II | 98 | 2 | 0 | 0 | 64 |
| " | III | 90 | 9 | 1 | 0 | 70 |
| " | IV | 82 | 18 | 2 | 0 | 56 |
| " | V | 47 | 21 | 11 | 21 | 19 |
| " | VI | 95 | 5 | 0 | 0 | 41 |
| " | VII | 83 | 14 | 3 | 0 | 29 |
| " | VIII | 95 | 3 | 0 | 3 | 37 |
| " | K* | 95 | 0 | 5 | 0 | 44 |
| Trace | I | 33 | 47 | 13 | 7 | 15 |
| " | II | 60 | 20 | 20 | 0 | 5 |
| " | III | 17 | 67 | 17 | 0 | 6 |
| " | IV | 33 | 50 | 17 | 0 | 6 |
| " | V | 25 | 0 | 25 | 50 | 4 |
| " | VI | 33 | 67 | 0 | 0 | 6 |
| " | VII | 40 | 40 | 20 | 0 | 5 |
| " | VIII | 50 | 50 | 0 | 0 | 2 |
| " | K* | 25 | 25 | 50 | 0 | 4 |
| LE 0.10 | I | 13 | 0 | 37 | 50 | 24 |
| " | II | 100 | 0 | 0 | 0 | 1 |
| " | III | 100 | 0 | 0 | 0 | 1 |
| " | IV | 0 | 60 | 40 | 0 | 5 |
| " | V | 24 | 24 | 29 | 24 | 17 |
| " | VI | 33 | 0 | 67 | 0 | 3 |
| " | VII | 62 | 31 | 8 | 0 | 13 |
| " | VIII | 0 | 0 | 0 | 0 | 0 |
| " | K* | 0 | 33 | 33 | 33 | 6 |
| GT 0.10 | I | 0 | 0 | 42 | 58 | 12 |
| " | II | 0 | 0 | 0 | 0 | 0 |
| " | III | 50 | 0 | 50 | 0 | 2 |
| " | IV | 0 | 0 | 0 | 0 | 0 |
| " | V | 0 | 11 | 50 | 39 | 18 |
| " | VI | 0 | 100 | 0 | 0 | 1 |
| " | VII | 50 | 0 | 25 | 25 | 4 |
| " | VIII | 0 | 0 | 0 | 0 | 0 |
| " | K* | 0 | 0 | 25 | 75 | 4 |

*Map type K consists of all maps with a correlation coefficient LT 0.70 with all of the other types.

N = the number of forecasts made using a particular procedure = 585

r = the number of precipitation categories = 4

f_{ij} = probability of precipitation category j forecast on the i^{th} forecast

E_{ij} = 1 if the 1000 LST precipitation was in category j and 0 if not.

Table 6 gives the "P" scores for the ten forecast procedures.

Table 6. "P" Scores Resulting From Applying Each of Ten Forecast Procedures

| Set | Forecast Procedure | "P" Score |
|-----|--------------------------------|-----------|
| 1. | Climatology | 0.504 |
| 2. | Conditional climatology | 0.385 |
| 3. | General types | 0.426 |
| 4. | Smooth general types | 0.425 |
| 5. | Stratified types | 0.411 |
| 6. | Smooth stratified types | 0.411 |
| 7. | Initial plus general | 0.330 |
| 8. | Initial plus smooth general | 0.326 |
| 9. | Initial plus stratified | 0.317 |
| 10. | Initial plus smooth stratified | 0.323 |

The best (lowest) score is achieved when both the initial (0400 LST) precipitation and stratified map type is considered. The best single predictor is the initial precipitation category; that is, conditional climatology with a score of 0.385. If the initial condition is not known, the stratified types and the smooth stratified types yield the best score.

9. REMARKS

Although there is evidence that probability estimates based on map types generated after the data are stratified, according to subsequent weather category are better; that is, result in lower "P" scores than estimates based on unstratified types prepared for general usage, the statistical significance of the difference in the "P" scores cannot be determined without testing on a large sample of independent data. Since we were unable to obtain a large sample of independent data, we cannot say with any large degree of certainty that stratification is important. Since stratifying reduces the sizes of the sub-samples, a long record of past weather is needed

to provide sufficient predictor and predictand data to generate map types and obtain reliable probability estimates.

Since general map types are generated without regard to subsequent weather category, independent sample testing is less critical. The relative frequencies given in Table 4 are substantial departures from the unconditional relative frequencies given in Table 1. They demonstrate what might be gained in longer range forecasting if accurate prognostic charts of 1000 mb heights were available. The relative frequencies given in Table 5 and the "initial plus general" score of 0.330 in Table 6 indicate that the addition of map type information to conditional climatology tables significantly improves estimates of the probability of future precipitation categories. However, many of the sample sizes in Table 5 are small, resulting in possible large departures between the estimated probabilities and true probabilities.

There is no evidence that smoothing, by averaging a number of similar maps, significantly improves a particular map type.

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